FORAGE & GRAZING LANDS

Forage Production and Nutritive Value of Selected Pigeonpea Ecotypes in the Southern Great Plains

S. C. Rao,* S. W. Coleman, and H. S. Mayeux

ABSTRACT

Stocker cattle production in portions of southern Great Plains depends on wheat (*Triticum aestivum* L.) and warm-season perennial grasses. Nutrient supply is limited in both quantity and quality from late July through November. To determine if pigeonpea [*Cajanus Cajan* (L.) Millsp.] could fill this deficit, a field study was conducted from 1996 to 1998. Seasonal forage production patterns, yield, and quality of three pigeonpea ecotypes (ICP8151, ICPX910007, and PBNA) were evaluated. Pigeonpeas produced 5 Mg ha^{-1} dry matter by 26 August, with N concentration >20 g kg^{-1} and digestible dry matter (DDM) > 500 g kg^{-1}. Ecotype ICPX910007 accumulated greatest dry matter in 136 d (16 Mg ha^{-1}), followed by ICP8151 (13 Mg ha^{-1}) and PBNA (9.5 Mg ha^{-1}). Mean N concentration for PBNA was 28.6 g kg^{-1} as compared with 23.3 and 23.0 g kg^{-1} for ICP8151 and ICP910007, respectively. Digestible dry matter of PBNA was 614 g kg^{-1}, followed by 576 and 572 for ICP8151 and ICP910007, respectively. Leaf dry matter yield averaged across sampling dates and years for all ecotypes ranged from 2360 to 2600 kg ha^{-1}. Leaf quality was similar to that of alfalfa for all ecotypes. Environmental conditions such as cooler spring and summer temperatures and excess rainfall (1997) or extreme drought (1988) reduced yield of all ecotypes. Pigeonpea can provide high-quality forage that could be used as a primary or supplementary forage for grazing livestock at a time when other forages are less productive.

A BASIC GOAL of grazing programs is to provide high-quality forage year-round to reduce costs of storing and purchasing forage or concentrate feeds. No single crop has the potential to provide forage year-round. One of the traditional approaches to agricultural production in the southern Great Plains is based on stocker cattle production, grazing a primary forage source, winter wheat. Wheat pasture is grazed during the winter and early spring. It is often used as a dual-purpose forage and grain crop. Warm-season perennial grasses such as bermudagrass [*Cynodon dactylon* (L.) Pers.] and old world bluestems (*Bothriochloa* spp.) provide forage during the late spring and early summer. However, high-quality forage is unavailable from late July through late November, when quality and quantity of summer perennial grasses have declined and winter wheat is not yet sufficiently established and productive for grazing. Therefore, additional forage resources with the ability to supply forage during the deficit period are needed for use in sustainable forage-livestock production systems in the southern Great Plain region.

Pigeonpea is a summer legume crop grown for grain in the tropics and subtropics. The crop ranks sixth in the world in production of dryland legumes (Nene and Sheila, 1990). Pigeonpea can survive well in degraded soil and tolerates moisture stress, perhaps due to its deep root system. It also has potential for use in soil conservation (Sheldrake and Narayanan, 1979). Pigeonpea has for centuries been used as high-protein grain for human food (Whiteman and Norton, 1981) and animal feed because it produces large amounts of biomass with high protein content (Pathak, 1970; Wallis et al. 1986; Whiteman and Norton, 1981; and Whyte et al., 1953). For example, late-maturing pigeonpeas (265 to 340 d after seeding) grown in relatively frost-free areas produced 36 Mg ha^{-1} of dry matter in Kanpur, northern India (Singh and Kush, 1981), 52 Mg ha^{-1} in Columbia (Herrera et al., 1966), and 46 Mg ha^{-1} in western Australia (Parbery, 1967).

Chemical composition of pigeonpea varies with age, maturity, and the proportion of plant components such as leaf, stem, flower, seed, and pods. Akinola and Whiteman (1975) measured N concentration of plant parts at different growth stages and reported that 4-wk-old leaves and stems contained 48 and 27 g kg^{-1}, which declined to 36 and 18 g kg^{-1} at 16 wk, respectively. Cattle carrying capacity of good pigeonpea stands ranged from 1.2 to 3.7 animals ha^{-1} with an average live-weight gain of 1 kg animal^{-1} d^{-1} (Kruss, 1932). In Hawaii, Henke et al. (1940) suggested that pigeonpea forage was superior to grass when compared in terms of gain per animal, and it could carry a higher stocking rate than grass.

Pigeonpea is not grown in the southern Great Plains; however, it has potential as a productive, high-quality forage during a period when conventional forages are not available. The objective was to evaluate the seasonal forage production patterns and nutritive value of selected pigeonpea ecotypes during the summer fallow period of winter wheat.

MATERIALS AND METHODS

Studies were conducted during the summer fallow period in a continuous winter wheat production system at the Grazinglands Research Laboratory near El Reno, OK (35°40′ N, 98°0′ W, elevation 414 m). Mean maximum and minimum temperatures at this location during the June to September growing season are 36°C and 20°C, respectively. The long-

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Abbreviations: DDM, digestible dry matter.

Table 1. Mean monthly precipitation and temperature for May through September 1996 to 1998, and the 25-yr average at the study site.

	Precipitation				Temperature			
Month	1996	1997	1998	25-yr avg.	1996	1997	1998	25-yr avg.
	cm				°C			
May	7.8	15.8	6.3	16.2	23.3	18.4	21.5	21.0
June	6.1	18.2	6.7	12.5	25.7	23.1	25.8	26.0
July	11.7	10.3	0.0	5.5	27.5	26.2	29.7	29.0
August	22.0	12.6	0.8	6.6	25.4	24.6	27.3	28.0
September	8.3	4.5	1.5	9.0	20.8	22.7	25.7	24.0
Total	55.9	61.5	15.4	49.8				

term average precipitation during the growing season is 49 cm. Average date of the first killing frost is ≈2 November. Soil on the experiment site was Dale silt loam (fine-silty, mixed, superactive, thermic, Pachic Haplustolls) with a pH of 6.6.

Three pigeonpea ecotypes were selected for study on the basis of wide variation in growth habit when observed in the germplasm evaluation plots at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in Patancheru, India. These included the late-maturity ICP8151, the intermediate-maturity ICPX910007-20-B-B, and the dwarf late-maturity PBNA 1XICPL366G16-B-B. Plots were disced and 60 kg ha^{-1} of P_2O_5 was applied in late May of each year. No N fertilizer was applied. Seeds were inoculated with multistrain inoculum and seeded at the rate of 30 kg ha^{-1} with a row spacing of 60 cm. Each plot was 3-m wide and 20-m long. The same ecotypes were repeatedly planted on the same plots throughout the study (treatments were fixed in space).

Forage quantity and quality were evaluated on five sampling dates beginning after about 60 d of growth on 7 July and ending on 3 October, ≈136 d after seeding. Every effort was made to maintain consistent planting and sampling dates. Whole-plant samples were hand clipped at 2.5 cm above the ground from three randomly selected 0.5-m lengths of row in each plot. Plant samples were collected at a new location at each sampling date. Plant samples were dried in a forced-draft oven at 65°C for at least 60 h, separated into leaf and stem, and ground to pass a 1-mm screen. These were analyzed for N concentration using a complete combustion N analyzer (Leco CHN-1000, Leco Corp., St. Joseph, MI)[1], and for in vitro DDM by near-infrared reflectance spectroscopy calibrated with data from 10% of the samples analyzed using the two-stage technique of Tilley and Terry (1963) as modified by Monson et al. (1969). Spectral data were collected on all samples, average of 32 scans for each sample, with a NIR Systems 6500 spectrophotometer (Foss Int., Silver Springs, MD) equipped with a static sample cup device.

Principle component analysis was conducted on the spectral data and on a subset selected for calibration using the > Select = procedure of the software InfraSoft International (ISI, Port Matilda, PA), based on spectral dissimilarity of samples (Schenk and Westerhaus, 1991a). Reference laboratory data for DDM were compared with the spectral data for the calibration samples and equations were developed with the ISI software using partial least squares regression (Schenk and Westerhaus, 1991b). The DDM mean, standard error of validation, and r^2 for the equation used were: 568 g kg^{-1}, 29.8 g kg^{-1}, and 0.97, respectively. The equations were then used to predict DDM for all samples, including those used for calibration. The three pigeonpea ecotypes were arranged in a split-split-plot, randomized complete block design with three replications. Main-plot effects were assigned to ecotypes, years were considered subplots, and sampling dates during the growing season as sub-subplots. Mean separations were done by least-significant difference using pooled mean square error.

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by USDA and does not imply its approval to the exclusion of other products that may be suitable.

RESULTS AND DISCUSSION

The amount and distribution of precipitation during the growing season varied among years (Table 1). Precipitation in 1996 and 1997 was slightly greater (5–11 cm) than the 25-yr average. Precipitation during the 1998 growing season was 70% lower than the 25-yr average. Mean daily temperatures for the three growing seasons were 25°C in 1996, 23°C in 1997, and 26°C in 1998, compared with 25°C for the 25-yr average. Pigeonpea is a tropical legume that requires a base temperature of 12.8°C for germination and 58 heat units for emergence (Angus et al., 1980).

Whole Plant Responses

Whole-plant dry matter yield varied among ecotypes, years, and sampling dates. The year by sampling date interactions were significant ($P < 0.01$) for all parameters measured. An ecotype × sampling date interaction was also observed ($P < 0.01$) for whole plant dry matter yield (Table 2). Total whole-plant dry matter yield for all ecotypes was greater ($P < 0.01$) in 1996 as compared with 1997 and 1998 (Fig. 1). The higher production in 1996 could be attributed to a more even distribution of precipitation and near normal temperatures. The lower total dry matter yield in 1997 may have been due to slightly cooler temperatures and precipitation greater than the 25-yr average. McGuire et al. (1998) reported that excess precipitation and cooler temperatures reduced yields of winter legumes. Although the 1998 growing season was dry and warmer than the previous two growing seasons, total dry matter yield was similar to 1997. Senthong and Pandey (1989) reported that yields of mungbean [*Vigna radiata* (L.) R. Wilczek], soybean [Glycine Max (L.) Merr.], cowpea [*V. unguiculata* (L.) Walp.], and peanut (*Arachis hypogaea* L.) were reduced in the driest weather regime of their study, but yield of pigeonpea was unaffected. This suggests that pigeonpea is well suited for rainfed areas where a moisture deficit may be expected during the summer fallow periods.

When averaged across years, dry matter yield of pigeonpea ecotypes did not differ ($P \leq 0.05$) on three of five sampling dates (Table 3). By the last sampling date, ecotype ICPX910007 had accumulated the greatest dry matter (15.8 Mg ha^{-1}), followed by ICP8151 (12.5 Mg

Table 2. Combined analysis of variance of whole-plant, leaf, and stem dry matter yield (DMY), N concentration, and digestibility dry-matter (DDM), for all years and sampling dates.

Source	df	Plant DMY	Leaf DMY	Stem DMY	Plant N	Leaf N	Stem N	Plant DDM	Leaf DDM	Stem DDM
Rep (R)	2	ns†	ns	ns	ns	ns	ns	ns	ns	ns
Ecotype (E)	2	**	ns	**	**	ns	**	**	**	ns
Error A	4									
Year (Y)	2	**	**	**	**	**	ns	**	**	*
Y × E	4	ns	ns	ns	ns	ns	*	ns	ns	ns
Error B	12									
Day (D)	4	**	**	**	**	**	**	**	**	**
E × D	8	**	ns	**	ns	ns	ns	ns	ns	ns
Y × D	8	**	**	**	**	**	**	**	**	**
E × Y × D	16	ns	ns	ns	ns	ns	ns	ns	ns	ns
Residual	72									

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
† ns = not significant at 0.05 level of probability.

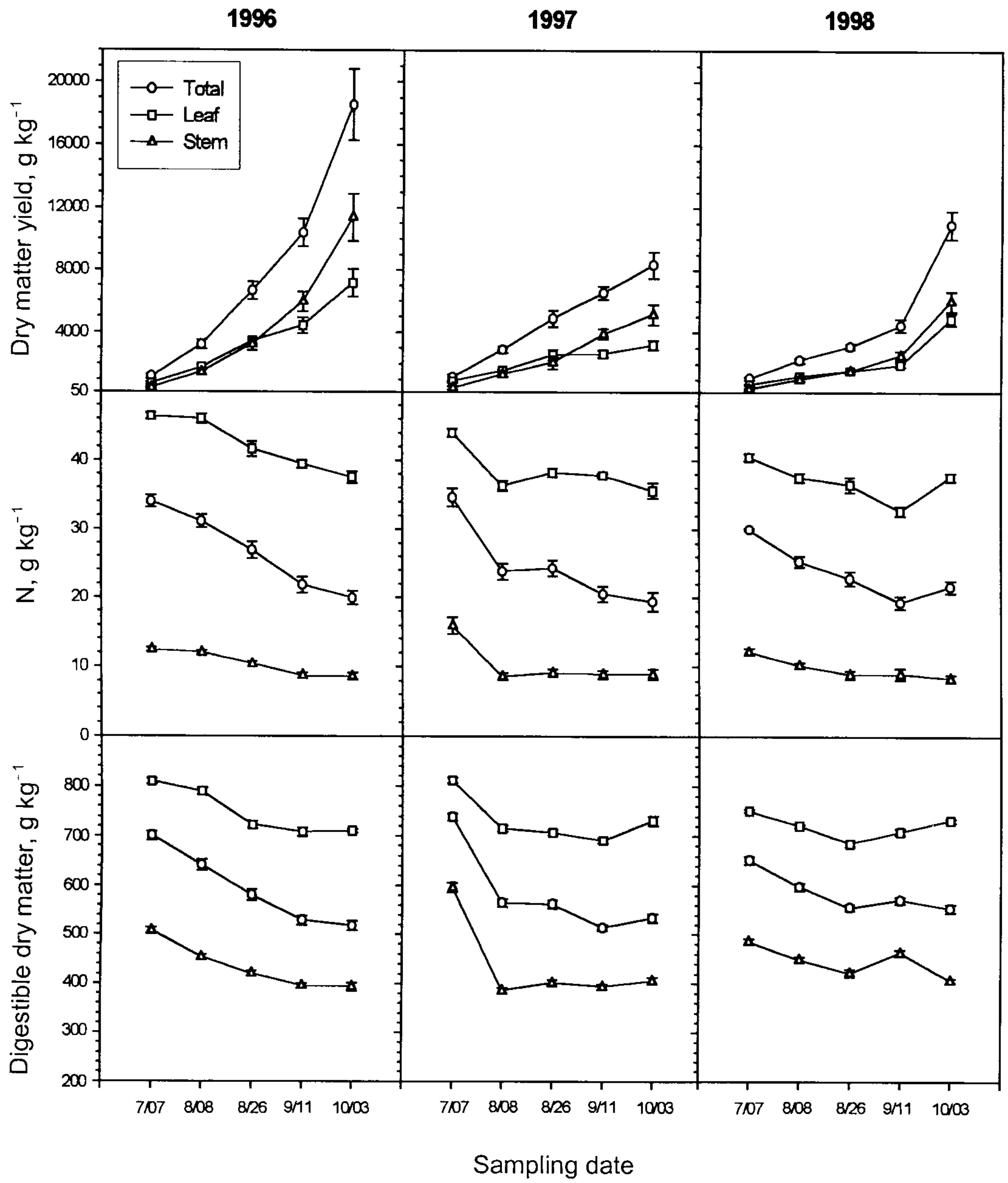

Fig. 1. Dry matter yield, N concentration, and digestible dry matter of pigeonpea whole plants, leaves, and stems averaged across ecotypes. Standard errors of each mean are presented as vertical bars.

Table 3. Dry matter yield of three pigeonpea ecotypes on five sampling dates, averaged across years.

Ecotypes	7 July	8 Aug.	26 Aug.	11 Sept.	3 Oct.
	Sampling dates				
	Mg ha^{-1}				
ICP8151	1.29a†	2.82a	5.26a	6.86a	12.53a
ICPX910007	1.14a	2.96a	5.84a	7.88a	15.80a
PBNA	0.93a	2.52a	3.56b	6.69a	9.47b

† In a column or a row means followed by same letter are not significantly different at $P \leq 0.05$.

Table 4. Mean dry matter yield (DMY), N concentration, and digestible dry matter (DDM) of leaves and stems of three pigeonpea ecotypes, averaged across sampling dates and years.

Ecotype	Leaf DMY	Leaf N	Leaf DDM	Stem DMY	Stem N	Stem DDM
	Mg ha^{-1}	g kg^{-1}		Mg ha^{-1}	g kg^{-1}	
ICP8151	2.36a†	39a	740a	3.34a	9b	435a
ICPX910007	2.77a	39a	735a	3.99a	9b	436a
PBNA	2.60a	39a	722b	2.03c	12a	443a

† In a column, means followed by same letter within ecotypes are not significantly different at $P \leq 0.05$.

ha^{-1}) and PBNA (9.4 Mg ha^{-1}). Though PBNA dry matter yield tended to be least on all sampling dates, the differences in dry matter yield in late August and October were lower ($P < 0.05$) as compared with other two ecotypes. Total dry matter yield at the last sampling date for ICPX910007 and ICP8151 was similar to those reported by Norman et al. (1980) in Australia. Lower total dry matter yield for PBNA was associated with its dwarf, bushy stature. Nam et al. (1998) reported that dry matter yield in pigeonpea depends on light interception and radiation use efficiency. Bushy stature and overlapping of leaves may have reduced light interception. Power and Koerner (1994) and Clark and Myers (1994) reported that total dry matter yield for soybean, field pea (*Pisum sativum* L.), hairy vetch (*Vicia villosa* Roth), alfalfa (*Medicago sativa* L.), cowpea, and guar (*Cyamopsis tetragonoloba* (L.) Taub.) during the summer fallow period in Nebraska and Missouri ranged from 137 to 708 g m^{-2}, or considerably less than the average of 1260 g m^{-2} for the three pigeonpea ecotypes studied here.

Total biomass yield of pigeonpea in August and September was greater than that of bermudagrass yields at locations in Oklahoma (Taliaferro et al., 2000). Coleman and Forbes (1998) observed depressed animal gains on old world bluestem pastures during midsummer in Oklahoma. Gains were essentially zero by 20 August, although pasture growth and animal gains recovered later in the year due to late summer rainfall. Pigeonpea has the capability to maintain production even in years with severe drought, as was observed in 1998 in the present study.

Nitrogen concentration and DDM of whole plants of all ecotypes declined as the season progressed, but a year × sampling date interaction (Table 2) indicates that the patterns of decline differed among years (Fig. 1). The interaction occurred because in 1996 and 1998, N and DDM declined gradually until 26 August, then stabilized or even increased after 11 Sept. 1998. However, in 1997, N and DDM declined rapidly during the first two sampling dates (July 7 and August 8). This decline could be attributed to slightly cooler temperatures as compared with the other two growing seasons. Mean N content in PBNA was 28.6 g kg^{-1}, as compared with 23.3 and 23.0 g kg^{-1} for ICP8151 and ICP910007, respectively (calculated from Table 4). Higher dry matter yield for ecotypes ICP8151 and ICP910007 may have diluted nutrients, particularly N, reducing its concentration in the total biomass as compared with PBNA. Pigeonpea N concentrations compare favorably with those of other summer grain and forage legumes. Nitrogen concentration in lespedeza [*Kummerowia stipulacea* (Maxim.) Makino] was reported to be 16 g kg^{-1} (Rao and Phillips, 1999), alfalfa 23 g kg^{-1} (Hesterman et al., 1986), and soybean 24 g kg^{-1} (Devine et al., 1998). Digestible dry matter averaged across sampling dates and years was 614 g kg^{-1} for PBNA, followed by 576 and 572 g kg^{-1} for ICP8151 and ICP910007, respectively (calculated from Table 4). Digestible dry matter was equal to or greater than those reported for lespedeza and soybean, but were slightly lower than alfalfa (National Research Council, 1984). Differences in N and DDM contents were not significant for ICP8151 and ICPX910007.

Plant Parts

Leaf to stem ratio, averaged across ecotypes, were similar through the third sampling date, ≈26 August in each year (Fig. 1). Thereafter, stem biomass exceeded that of leaves. When averaged across years and sampling dates, leaf dry matter and N concentration were similar for all three ecotypes. However, the three ecotypes varied ($P < 0.05$) in stem dry matter yield (Table 4). Stem biomass of the ecotype PBNA was almost half that of ICPX910007, perhaps due to its dwarf stature. In addition, stem N concentration of PBNA was 33% higher than stem N concentration of other ecotypes, again a possible dilution of N in greater stem biomass. Pigeonpea ecotypes did not differ ($P < 0.05$) in DDM of the stem material (Table 4), but leaf DDM for PBNA was lower ($P < 0.05$) than that of the other two ecotypes. At 722 to 740 g kg^{-1}, leaf material of all ecotypes was much higher in DDM that would be expected for warm-season grasses grown at the same location during the late summer (Coleman and Forbes, 1998). Leaf dry matter was of high quality in terms of both N concentration and digestibility, at a time when growth of warm-season perennials had ceased and quality declined (Coleman and Forbes, 1998; Taliaferro et al., 2000).

The effects of year on yield and quality of leaves and stems were significant in that values were greater in 1996 than in 1997 and 1998 (Fig. 1). Higher precipitation and cool temperatures in 1997 and extremely dry conditions in 1998 resulted in lower production of both leaf and stem dry matter. Leaf N concentration and DDM averaged across ecotypes were lower ($P < 0.05$) under the dry conditions of 1998, as compared with the wet conditions of 1996 and 1997. The difference in N concentration was only 2 or 3 g kg^{-1}, representing a calculated difference of 12 to 18 g kg^{-1} of protein equivalent available to livestock. This difference would only be important if the overall N concentration was borderline in meeting animal protein needs, which was not the case.

SUMMARY AND CONCLUSION

All three pigeonpea ecotypes produced large quantities of high-quality forage during the summer fallow period when other available forage are inadequate. PBNA, a late-maturity, dwarf ecotype, produced 1120 to 2090 kg ha^{-1} less dry matter, but its N content and DDM were 5.3 to 5.6 and 38 to 42 g kg^{-1} greater, respectively, than ecotypes ICP8151 and ICPX910007. Though environmental conditions varied widely among growing seasons, effects of weather were mainly confined to total dry matter production with little effect on the nutritive value of pigeonpeas. Pigeonpea yields and nutritive values during the summer fallow period equaled or exceeded the yields and nutritive values of other forage crops reported for this region. These results suggest that pigeonpea has the potential to provide forage of high quality and adequate quantity for grazing livestock when other summer forages are unproductive.

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